Three-Dimensional Bayesian Geostatistical Aquifer Characterization at the Hanford 300 Area using Tracer Test Data

Xingyuan Chen[1,2], Haruko Murakami[1], Melanie S. Hahn[1]
Glenn E. Hammond[2], Mark L. Rockhold[2], and Yoram Rubin[1]

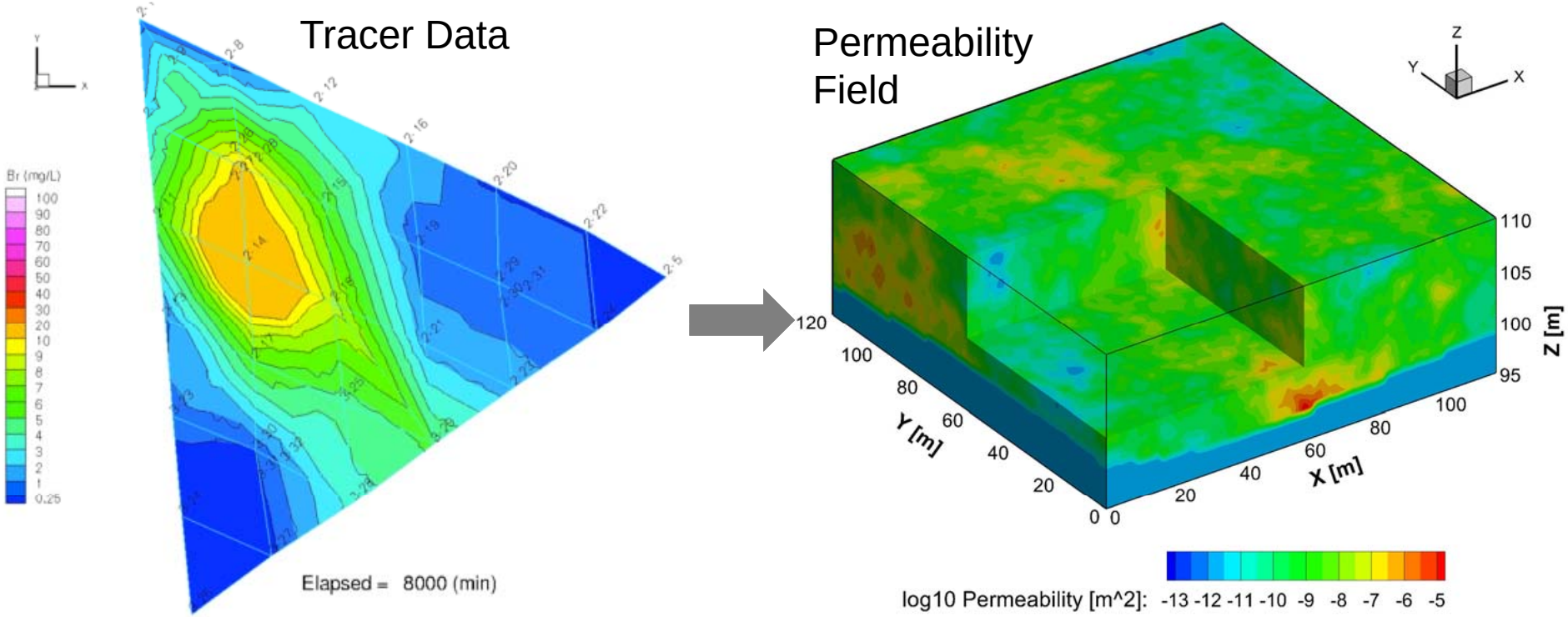
[1]University of California, Berkeley
[2]Pacific Northwest National Laboratory

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

OBJECTIVE OF STUDY

- To assimilate non-reactive tracer data into site characterization



- To consistently integrate other types of data

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

APPROACH

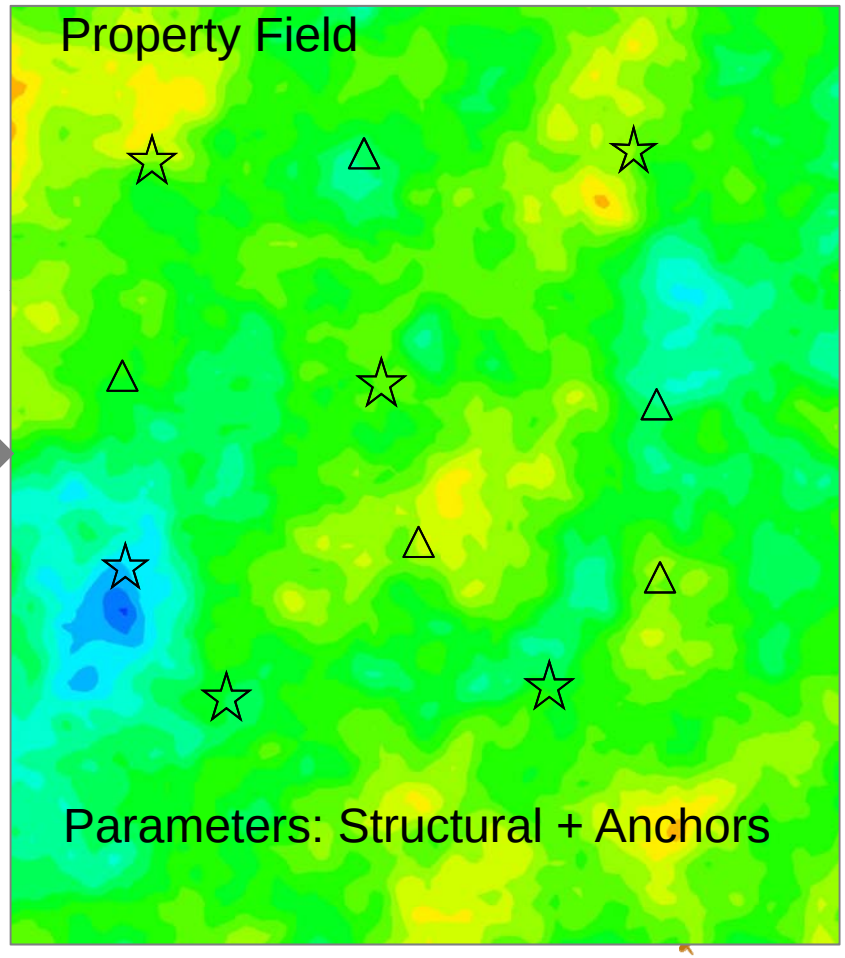
Method of Anchored Distributions (MAD) [Rubin et al.,WRR,2010]

Multi-Scale Multi-Type Data

Type A:
local, direct/regression
e.g., K, grain size, …

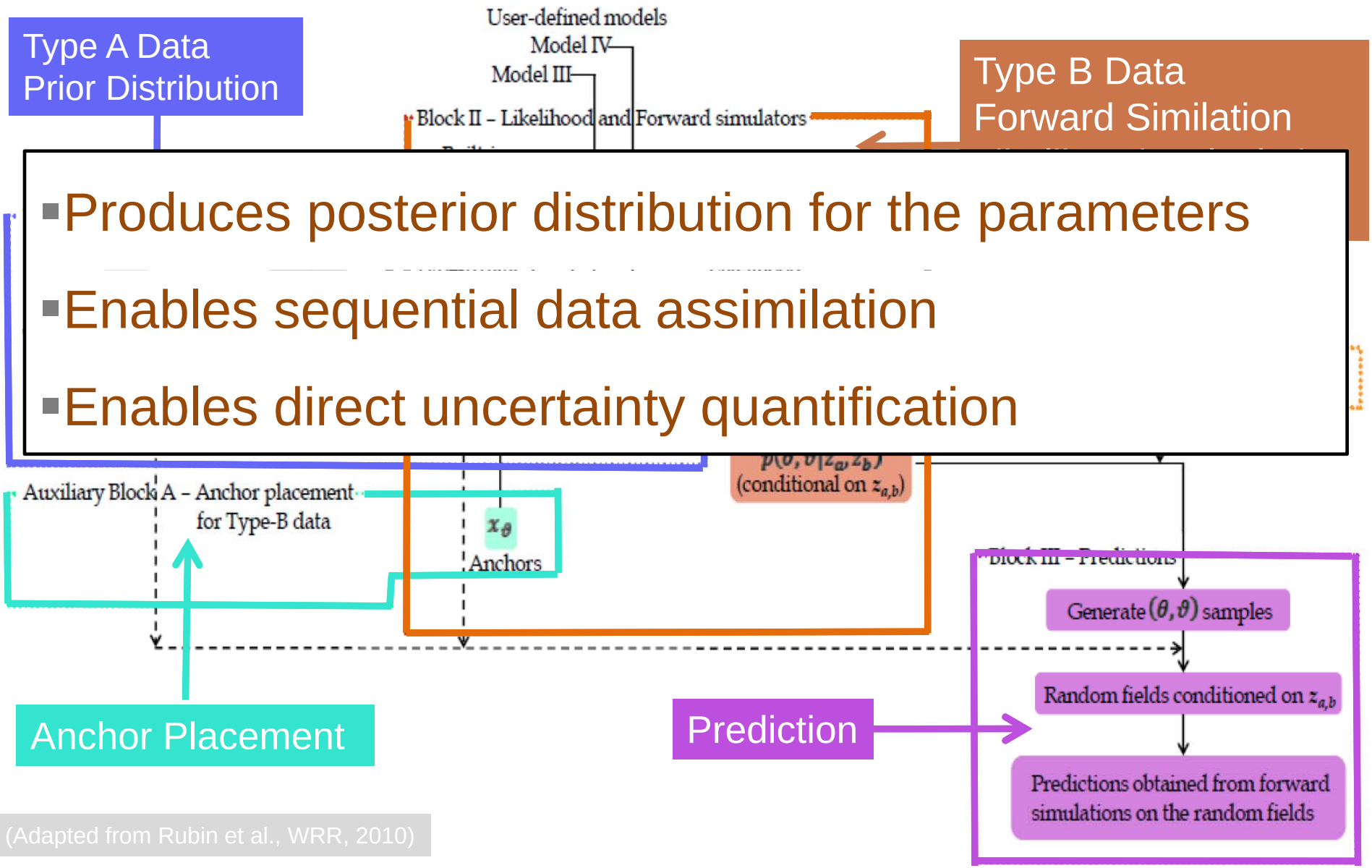
Type B:
Nonlocal, indirect
e.g., pumping test,
tracer test, …

MAD



Pacific Northwest
NATIONAL LABORATORY

MAD Framework: Bayesian

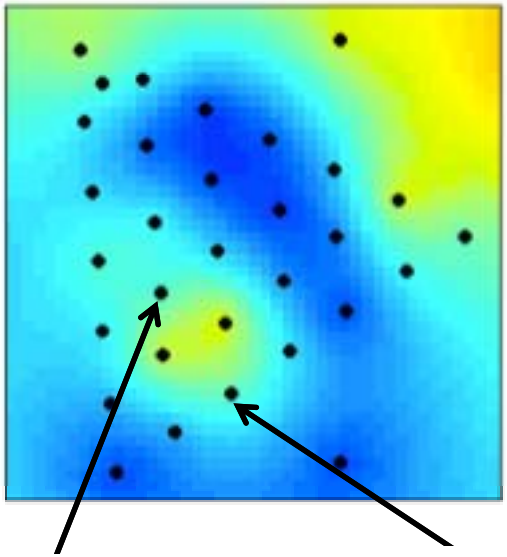


- Produces posterior distribution for the parameters
- Enables sequential data assimilation
- Enables direct uncertainty quantification

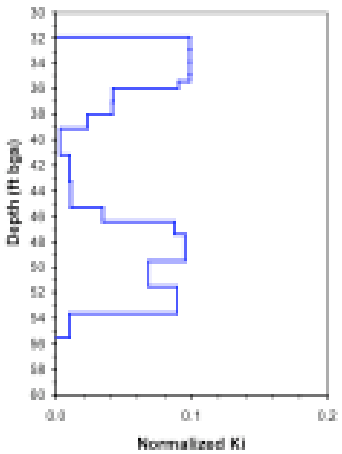
(Adapted from Rubin et al., WRR, 2010)

Prior Distribution

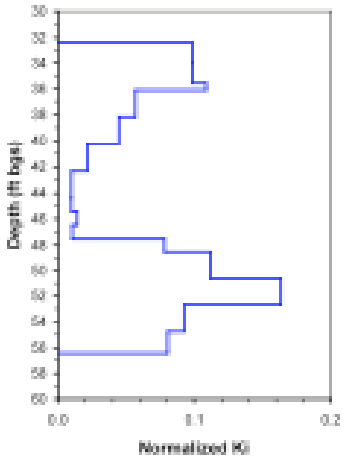
2-D Transmissivity Inverted from Constant Injection Tests



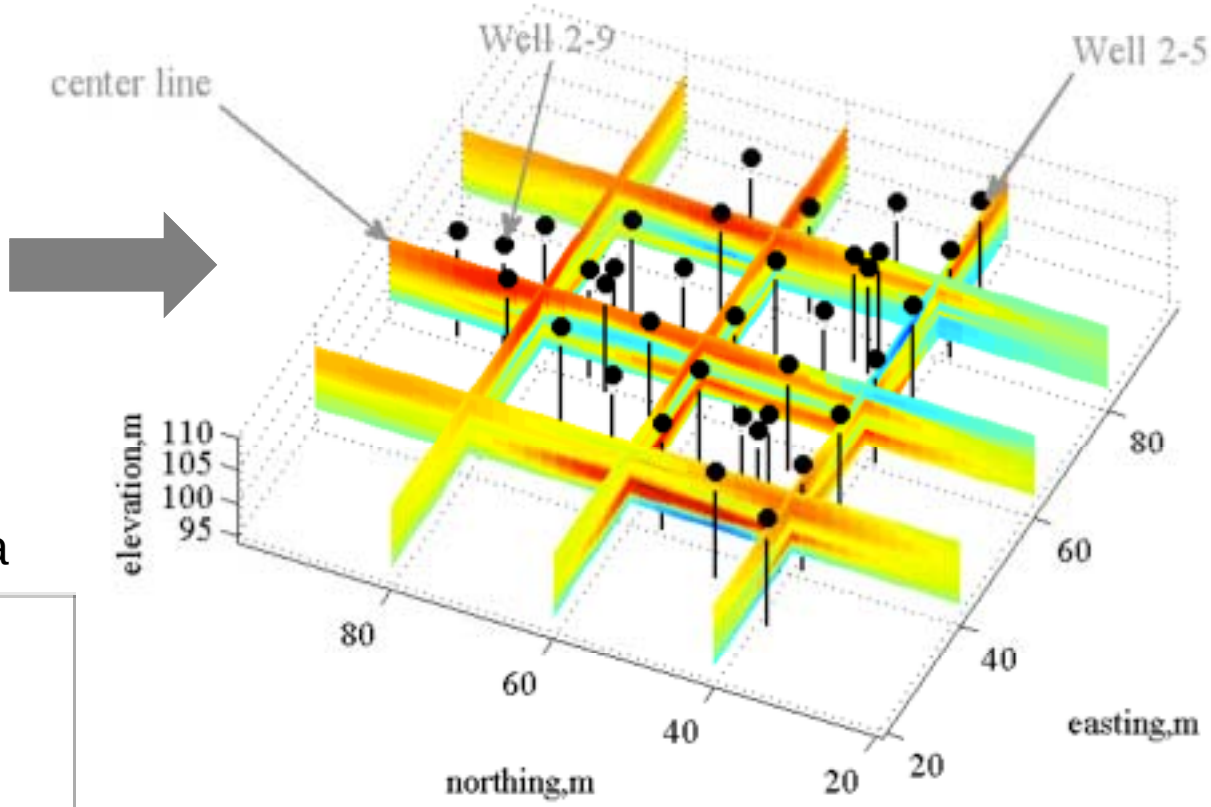
EBF Data



EBF Data



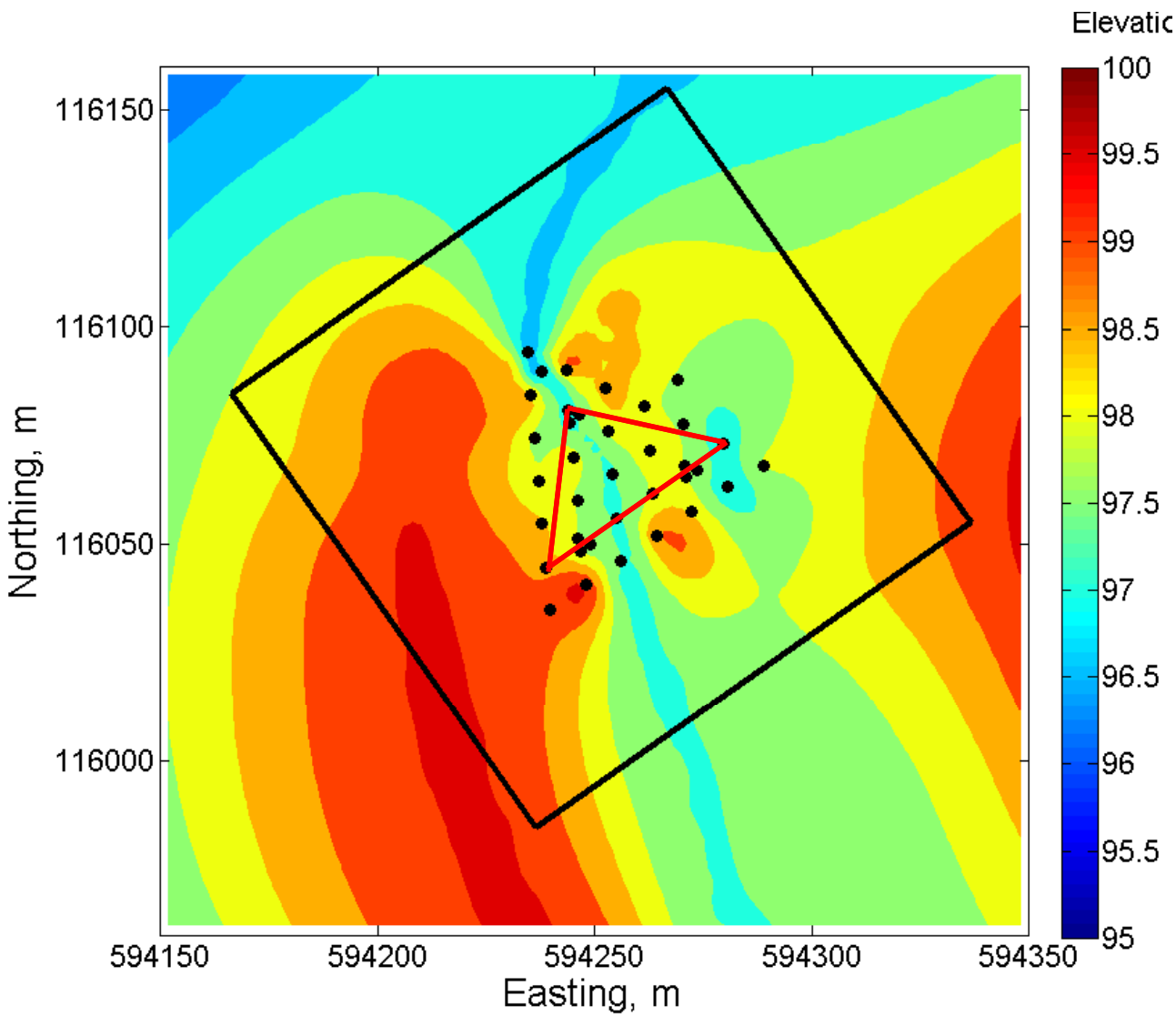
840,000 Realizations for inversion



Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

Forward Simulation



Domain:
120m×120m×10m
Grid size:
2m×2m×0.5m
Max Time Step:
1.0 hour
Simulation Time:
250 hours

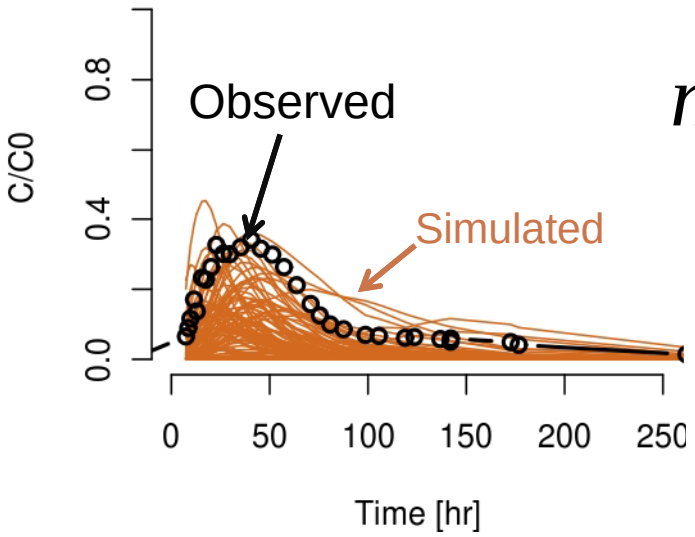
Fluctuating head boundary conditions

~40 min per field using PFLOTRAN

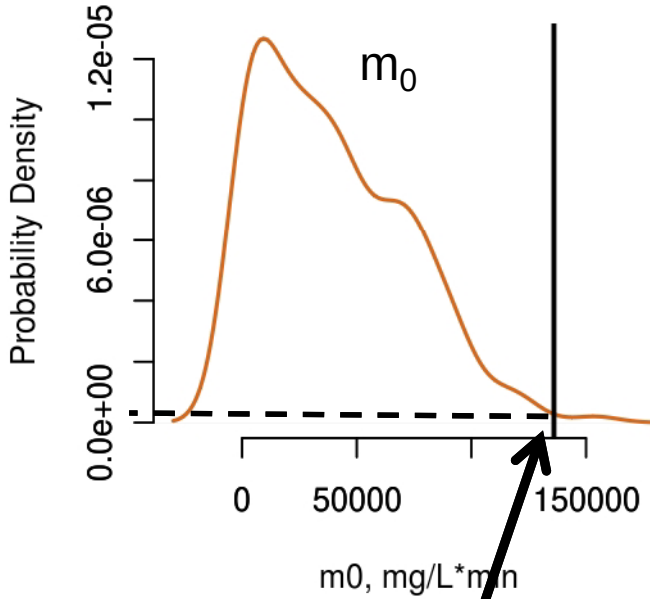
Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

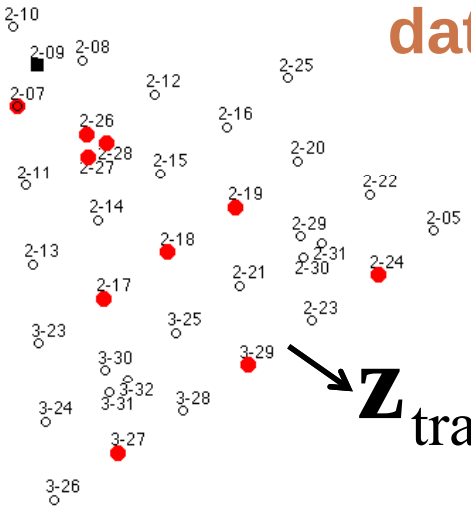
Likelihood Calculation



$$m_0 = \int_0^{\infty} c(t)dt$$



Temporal moments reduce data dimension



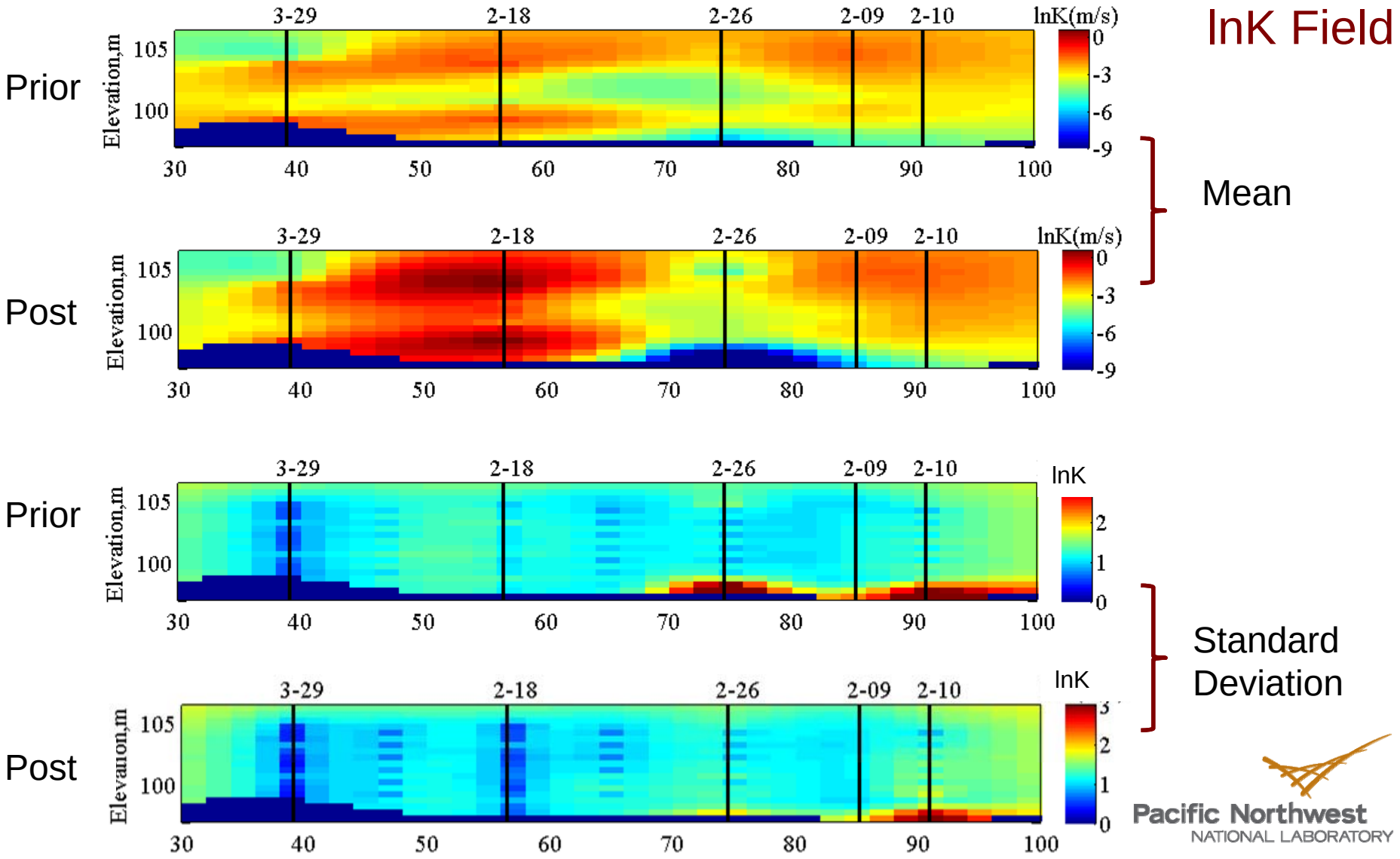
Likelihood: $p(\mathbf{z}_{\text{tracer}} \mid \theta, \vartheta)$

$$\mathbf{z}_{\text{tracer}} = \left(m_0^1, m_0^2, \ldots, m_0^n\right)$$

Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

RESULTS

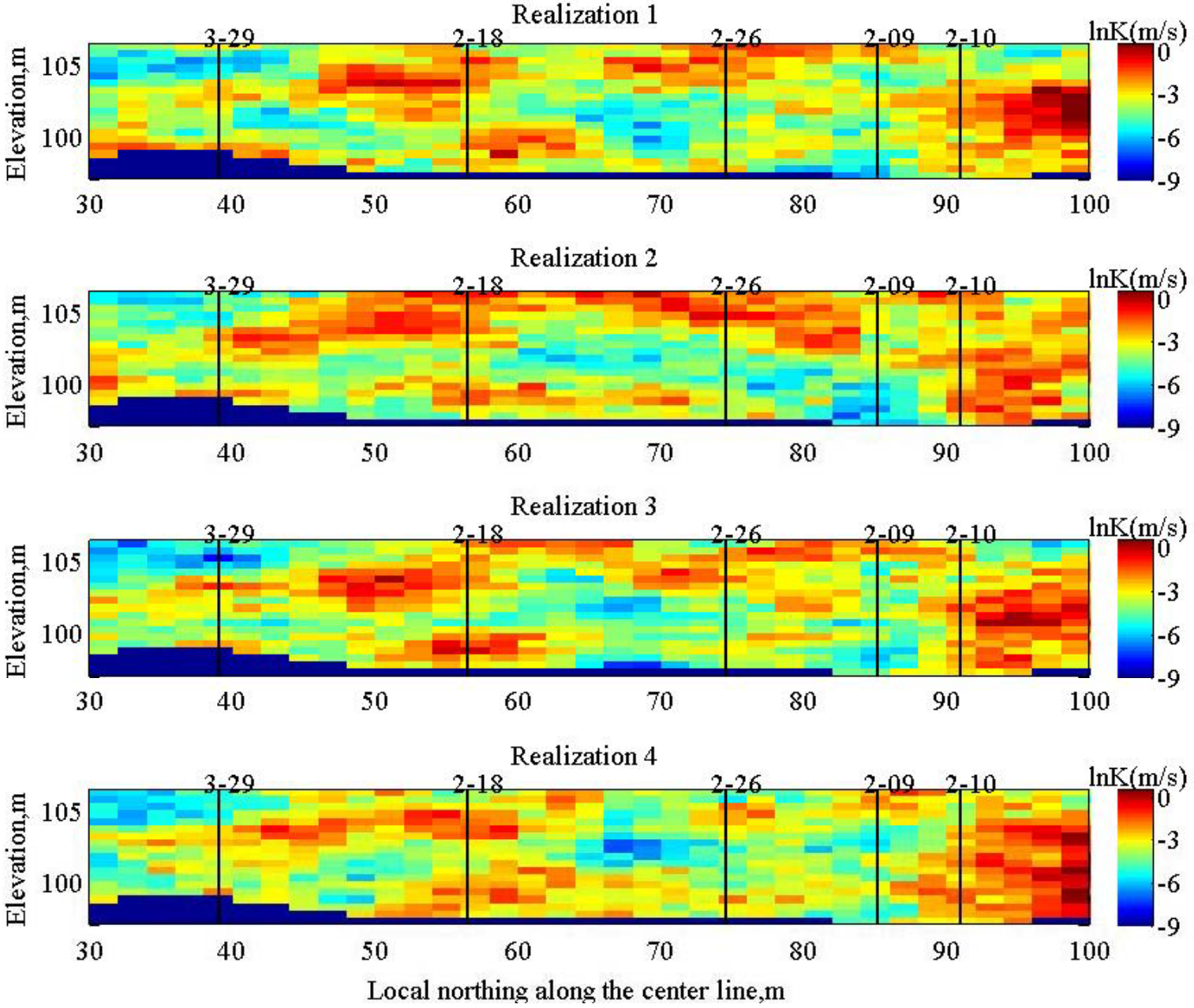


Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

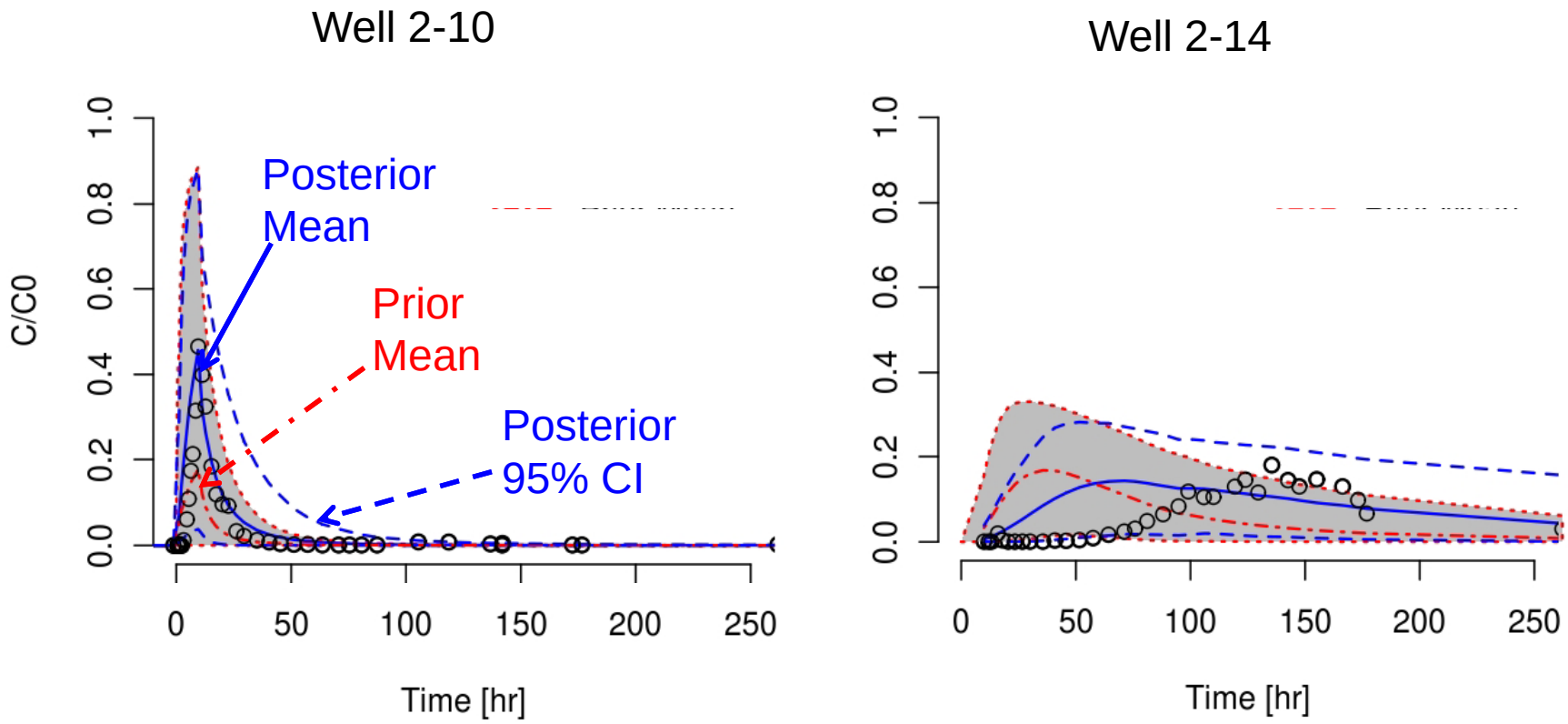
RESULTS

lnK Field



RESULTS

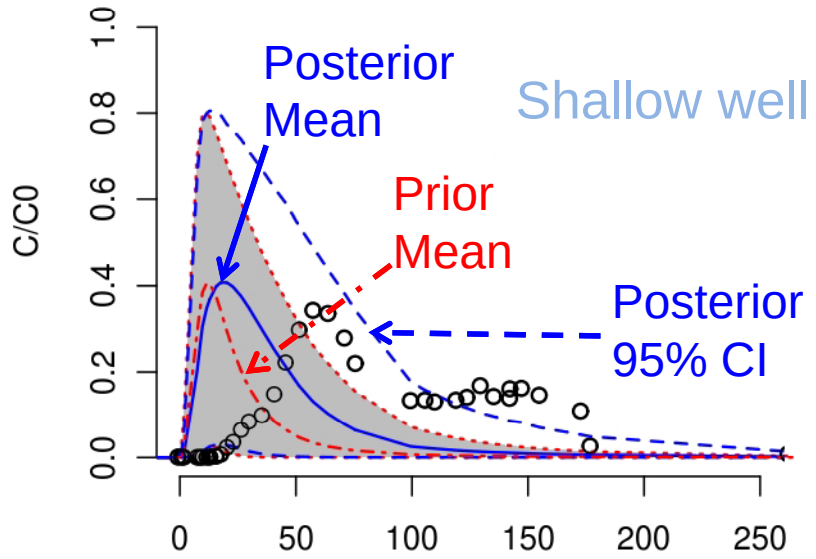
Tracer Breakthrough Curves

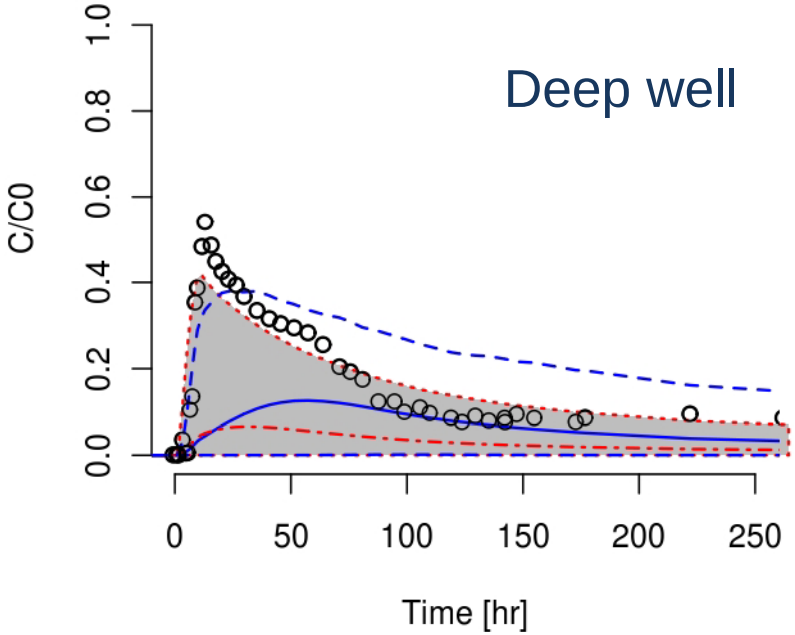


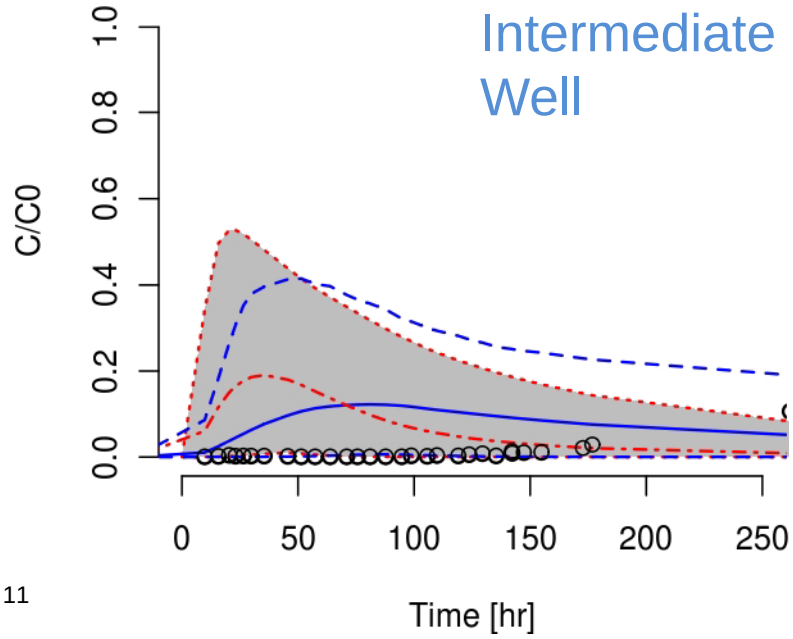
Pacific Northwest
NATIONAL LABORATORY

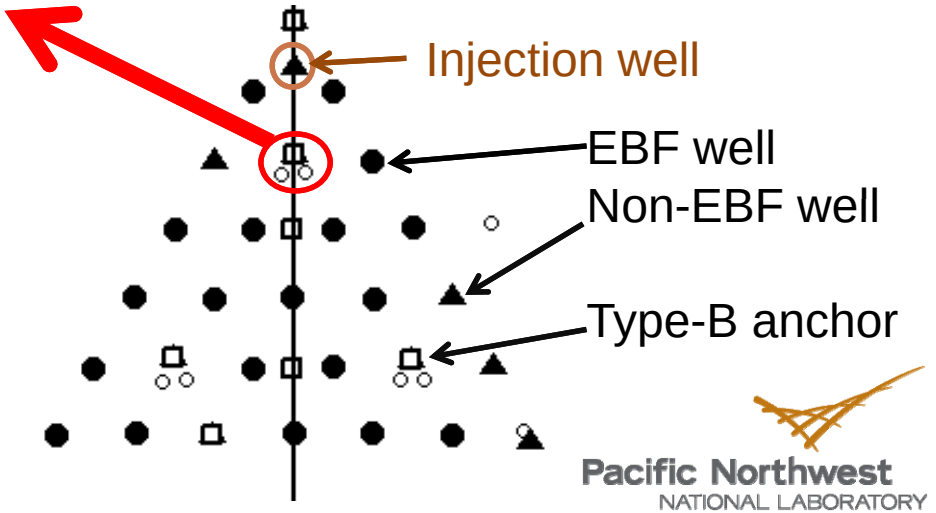
Proudly Operated by Battelle *Since 1965*

RESULTS







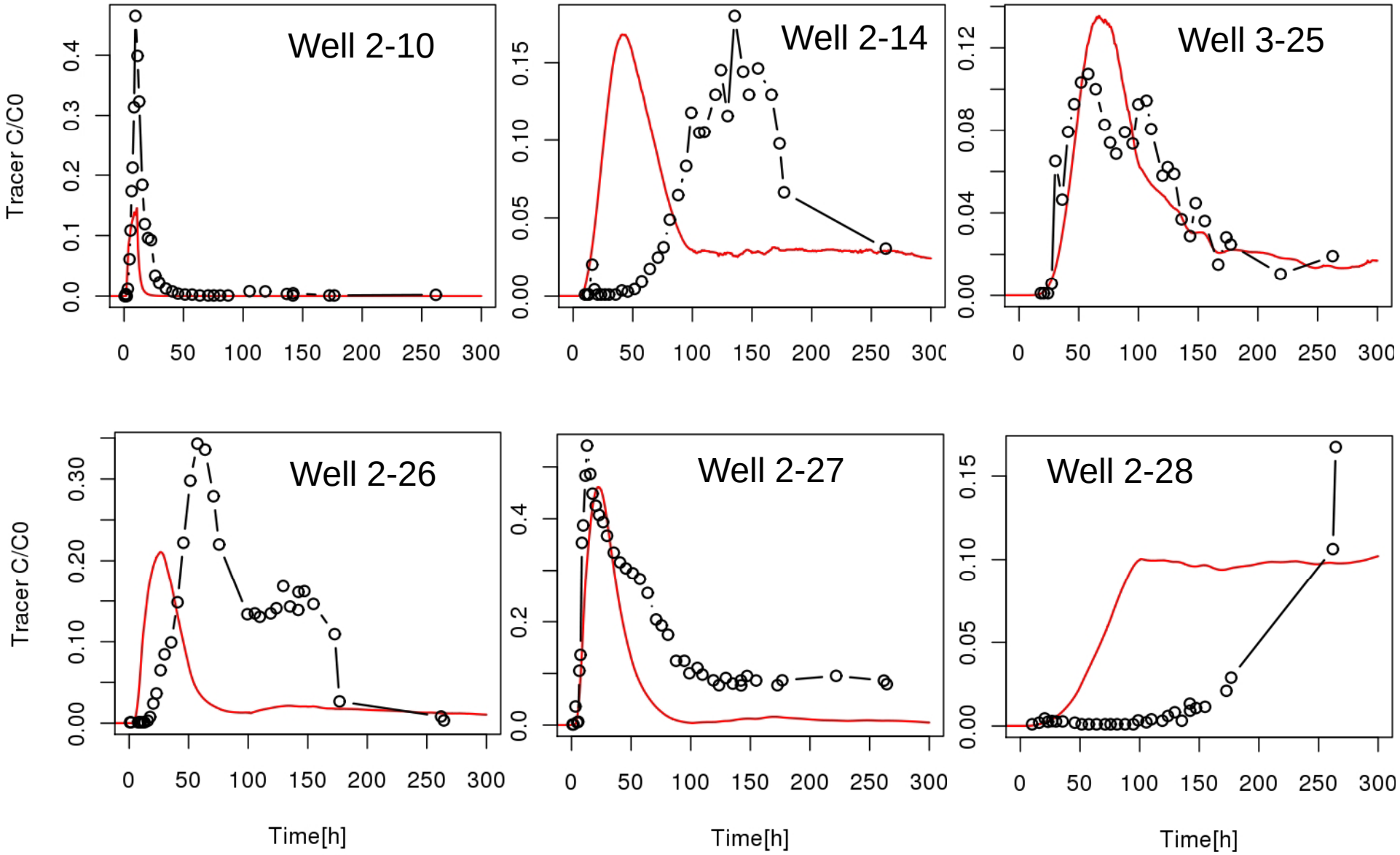


Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

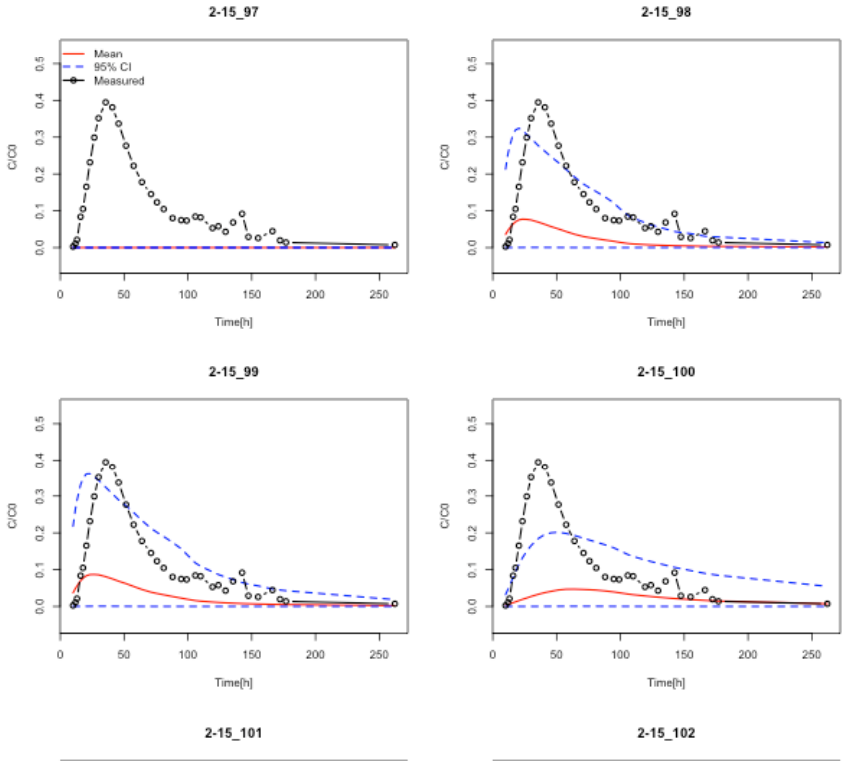
RESULTS

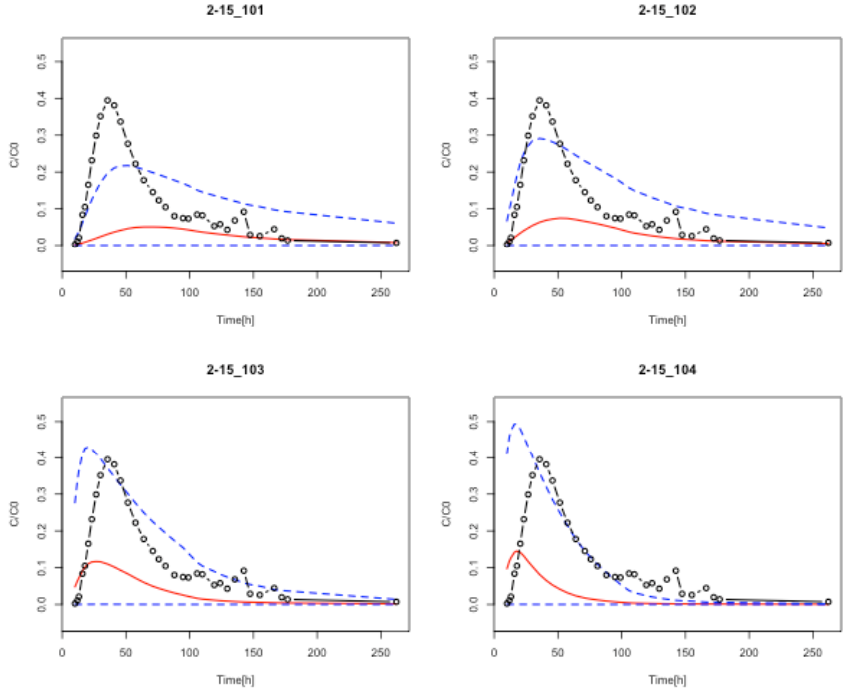
A Realization



RESULTS

Depth-Discrete



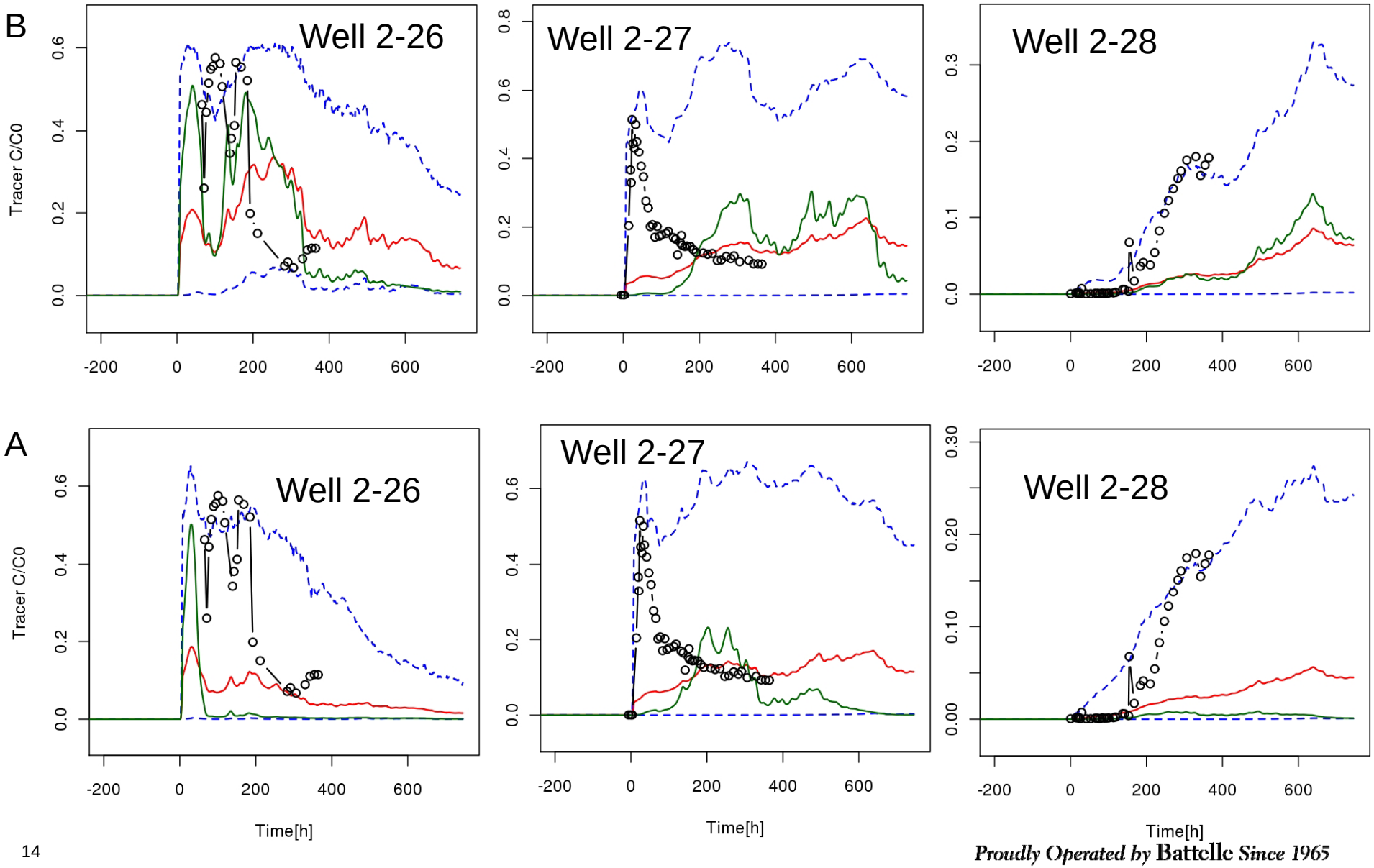


Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

RESULTS

Oct2009 Test



Summary and Future Work

- First-time application of MAD in 3-D inversion
- MAD shows good potential in assimilating multi-scale and multi-type data
- MAD enables sequential data assimilation and direct uncertainty quantification
- MAD is computationally expensive, but can be dealt with by high performance computing
- Future work needed to address uncertain flow boundary condition, vertical wellbore flow, and heterogeneous porosity field
- Multi-Gaussian assumption may be replaced

Pacific Northwest
NATIONAL LABORATORY

Acknowledgment

- DOE-SBR grant DE-FG02-06ER06-16 for IFRC project
- DOE-SC SciDAC2 program (PFLOTRAN development)
- Supercomputing provided by NERSC at LBNL
- Wolfgang Nowak for FFT field generation codes
- Hanford IFRC team

Thank you!